Report to the Chairman, Subcommittee on Projection Forces and Regional Defense, Committee on Armed Services, U.S. Senate

February 1990

SUBMARINE TECHNOLOGY

Transition Plans Needed to Realize Gains From DOD Advanced Research

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Information Management and
Technology Division

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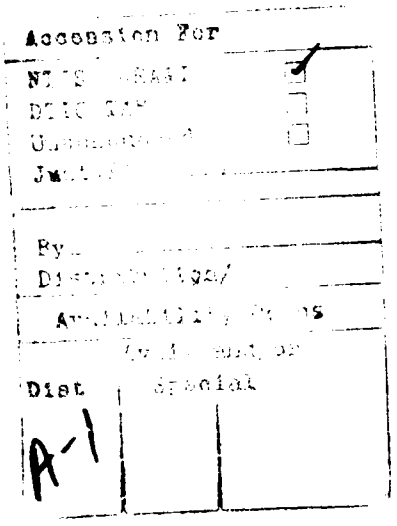
February 14, 1990

The Honorable Edward M. Kennedy
Chairman, Subcommittee on Projection Forces
and Regional Defense
Committee on Armed Services
United States Senate

Dear Mr. Chairman:



Your office requested that we (1) describe research efforts underway by the Department of Defense's Advanced Research Projects Agency (DARPA) on innovative submarine technologies, (2) assess plans for transitioning the research to the Navy for further development and implementation on submarines, and (3) determine whether the Navy is planning flexibility into the SSN-21 SEAWOLF attack submarine and its combat system to incorporate these technologies.

DARPA serves as the central research organization for the Department of Defense, performing various research projects designed to address many hardware, software, and technological issues facing the military today. Congress established the Advanced Submarine Technology Program (ASTP) in December 1987, to be executed by the Secretary of Defense through the Director of DARPA. The program was set up in light of the declining United States advantage in submarine technology. Congress directed that the ASTP program should explore innovative state-of-the-art technologies and establish a submarine technology base. The Congress has appropriated $303 million for ASTP for fiscal years 1988 through 1990. As of December 1989, DARPA had obligated $194 million and expended an estimated $117 million.[1]

Results in Brief

Under the ASTP program, DARPA is conducting technology research that could significantly improve submarine performance and increase the U.S. technological edge. However, the Navy has not developed a strategy for effectively transitioning ASTP research. Further, the Navy is not considering the ASTP research in designing the SEAWOLF submarine and is not planning the submarine design with features that will facilitate later implementation of technologies. Although a great deal of the technology research remains to be performed, the Navy could begin planning now to

[1] According to ASTP program office estimates, this represents the amount performing organizations have expended in conducting their contractual research work.

realize the gains from the ASTP technology research. Development of transition plans and procedures could help ensure the technologies are adequately considered for further development or incorporation on submarines currently being built and designed, including the SEAWOLF.

Background

Congress initiated the ASTP program because of the significant progress the Soviet Union has made in submarine development and the shrinking advantage of the United States in submarine technology. The Congress directed DARPA to research submarine technology because it was also concerned that "the Navy has discontinued most of its work in advanced submarine hull, mechanical, and electrical (HM&E) technologies...," and that "efforts by the Navy to develop submarine technology may not go far enough in terms of the threat posed by Soviet naval forces."[2] Historically, U.S. submarine quieting techniques and detection capability of enemy targets has allowed long detection range advantages that contributed directly to increased U.S. submarine survivability. According to Navy and DARPA officials, the Navy may not have emphasized research in specific submarine technologies because the U.S. had enjoyed long detection range advantages over Soviet submarines. However, according to DARPA, recent significant advances in Soviet submarine quieting and detection methods have lowered and will continue to lower the U.S. detection advantage.

In addition to DARPA's research under ASTP, the Department of the Navy also conducts research on submarine technologies. Within the Office of the Chief of Naval Research, the Office of Naval Technology and the Office of Naval Research have research responsibilities that complement some of the work being performed by DARPA under the ASTP program, as well as include other types of research such as weapons and sensor improvements. The two offices also act as agents for many of the ASTP projects. In addition, the Navy's Advanced Submarine Research and Development Office works with other Navy offices and DARPA to provide coordination, integration, and focus for advanced submarine research and development programs and submarine-related technology.

To facilitate Navy involvement in the ASTP research, the Congress established an ASTP Advisory Board in 1987. The board consists of Navy officials representing (1) research and development activities within the

[2]H.R. Rep. No. 410, 100th Cong., 1st Sess., at 233 (1987).

[3]H.R. Rep. No. 58, 100th Cong., 1st Sess., at 144 (1987).

Office of the Director of Research and Development Requirements, Test and Evaluation, the Office of the Chief of Naval Research, and the David Taylor Naval Ship Research and Development Center, (2) the attack submarine division of the office of the Assistant Chief of Naval Operations for Undersea Warfare, and (3) the Advanced Submarine Research and Development Office, as well as ASTP officials. The Board meets quarterly to provide general program advice and to facilitate discussion between Navy and DARPA officials on the status and the Navy's use of ASTP technology research. At its meetings, Board members discuss such topics as the status of individual projects, research successes, the relationship of ASTP research to Navy plans and research and development activities, and review and comment on ASTP documents such as the ASTP Long-Range Plan.

ASTP Submarine Technology Research

In carrying out the congressional intent of ASTP, DARPA is exploring new technologies as well as establishing technical centers and programs to build a knowledge base in specific areas where prior research is lacking. Many of these technologies involve long-term research and can only be implemented in a new submarine design. According to ASTP officials responsible for directing the research, other technologies could be available in the near-term and could be considered for use on existing submarines or those currently being built or designed. The objectives of the ASTP program are to

- identify and develop promising and revolutionary technologies that can provide new and innovative design options for future U.S. submarines;
- mobilize and focus the industrial, academic, and government research and development base to significantly improve future submarine performance; and
- demonstrate significant technologies and systems by rapid prototyping.

To perform the technology research, DARPA has awarded contracts to over 180 organizations and has organized ASTP into five major program areas, each managed by a separate program manager: (1) platform systems, (2) hydrodynamics, (3) materials, (4) mechanical and electrical, and (5) structural acoustics.

Platform Systems

Because of reduced U.S. submarine capability to detect enemy targets and the shorter amount of time available to respond to a threat, commanders must have more direct control of a submarine and knowledge

of the operating environment. Platform system research involves technologies designed to take the vast amount of raw data available on a submarine and turn it into information a commander needs to respond more quickly and accurately to threats. According to DARPA, automation techniques must be applied uniformly throughout the submarine platform, as a total system, to handle the large amount of information generated during operations. The platform systems research is concentrated in two main categories of technology: (1) electro-optical systems, and (2) a submarine operational automation system.

The development and application of advanced electro-optical systems could eliminate the need for rigid hull penetrating optical periscopes to make visual observations of the environment. Advancements in image processing, fiber optic links, and compact visual and infrared sensors are among the technologies being explored. One project that is being considered for transition to the Navy is a non-hull penetrating periscope. The benefits associated with this new periscope include increased stealth and surveillance capabilities and greater flexibility in submarine design, since the command center could be located in several areas of the submarine.

The submarine operational automation system is a long-term project that addresses the total automation of the submarine, including automating life support systems, submarine weapons and self-defense, sensor data processing, and command-level functions. This project will investigate automating manual functions using advances in computer hardware and software that could significantly enhance submarine performance. The system will use a computerized command center to assist the commander in performing the complex tasks and situations encountered in combat environments. Automating these functions is intended to provide the commander with real-time information on the status of the submarine and weapon systems, the location of enemy submarines, and ship maneuvering.

Hydrodynamics

Hydrodynamics influence a submarine's stealth, tactical speed, maneuverability, ship control, and propulsion. This program area is intended to provide the design capability to enable the submarine to maneuver more effectively in the ocean.

A Hydrodynamics/Hydroacoustics Technology Center is being developed to enable the Navy to quickly assess new design options and the impact modifications will have on current ship designs. For example,

some research is focused on improving the ability to model the effects of water flow through the submarine propeller and ways to reduce the associated noise and improve efficiency. Another Center project is the analysis of vortex systems generated by the interaction of the submarine with the ocean. As the submarine maneuvers through the ocean, cavities or vacuums are formed by the circular movement of seawater surrounding the submarine and its appendages (i.e., a whirlpool effect). This vorticity can affect maneuverability and the level of noise generated by the submarine. This project requires the development of reliable, automated computer systems to research ways for lessening the effects of vorticity.

Materials

The focus of the materials program area is to develop ways to use composite materials (materials other than steel, such as fiber-reinforced resin) for the pressure hull of submarines, as well as external and internal ship structures. Using composite materials for hulls can reduce a submarine's weight by 30 to 50 percent, reduce electromagnetic emissions that can be detected by enemy submarines, reduce or eliminate corrosion, and increase submarine design flexibility. In addition, DARPA is developing automated processing and control systems for sensors that would be embedded in submarine hulls to monitor the status of the composite material. New sensor concepts, sensor response, and fiber optic networks are among the technologies being explored.

Mechanical and Electrical

The mechanical and electrical program area is focused on developing technologies and system concepts different from the traditional propulsion and weapons launch methods used for the past 30 years. This research seeks to (1) reduce the weight and volume of propulsion machinery, (2) increase fire power by launching more weapons faster and more quietly, and (3) reduce electromagnetic emanations from the submarine that could be picked up by enemy submarines. For example, recent breakthroughs in semiconductor technology have made it possible to consider using solid state electrical components to reduce the size of motors and generators, increase reliability and maintainability, and include the potential for automation. Another project is addressing the feasibility of using non-nuclear fuel cells to provide long-term silent submerged auxiliary power for submarines.

Structural Acoustics

This program area will focus on both active and structural control. An active control system is made up of sensors that identify and counteract

the submarine's acoustic emission before enemy sonars can detect the presence of the U.S. submarine. Active control is a new area of study for the U.S.; previously the U.S. focused mostly on different methods to control noise generated by the submarine itself. Structural control is defined as using structural design and materials to control undesirable noise inside the submarine. In the past, the U.S. defined this research area narrowly, looking at structural acoustics and attempting to fix a problem after it was observed. However, the ASTP program will develop design and engineering options that will provide freedom in the design and construction of submarines. Because of the lack of a well established technical foundation in structural acoustics, much of the program's work lies in gaining a fundamental understanding of structural control and how major structural systems must be incorporated early in the design phase. Structural systems need to be a part of the initial design because they are difficult to insert into existing units.

Transitioning of DARPA Technology Research to the Navy

The key to achieving success with the ASTP technology research is transitioning it to the Navy for development and implementation. In its report on the 1989 Defense Appropriations Bill, the House Appropriations Committee stated that "...the ultimate success of this effort will depend to a large extent on the Navy acceptance through transition to Navy programs."[4] Further, the development of a transition strategy is a way to minimize the risk that valuable technology research may not be carried forward by the Navy, and avoid the loss of potentially significant technological submarine improvements.

The Navy has given its Advanced Submarine Research and Development Office responsibility for managing the transition of ASTP technology research to the Navy, and intends to report to Congress on transitioned ASTP projects. Yet, the Navy has not established criteria for determining how and when research projects should be considered for transition, nor has it established plans and procedures for monitoring and managing the transition of ASTP technology. According to DARPA's ASTP Long-Range Plan, key steps in transitioning of the technology research should include (1) developing a convincing analysis or demonstration of the potential benefits, (2) providing evidence of an appropriate level of technological maturity and practicability, and (3) developing an adequate long-range budget plan.

[4]H.R. Rep. No. 681, 100th Cong., 2nd Sess., at 188 (1988).

A transition strategy is needed because DARPA's objective under ASTP is to research innovative state-of-the-art and revolutionary technologies and concepts, rather than develop final products; thus at some point the Navy needs to decide whether to take over the technology research for development and implementation aboard submarines. Further, without adequate transition criteria, plans, and procedures, valuable technology research may not be continued since the Navy's top priority for submarine research is to fund those projects that offer improvements in the near-term, and that reduce the cost of the submarine. Because of this approach, there is no assurance that long-term ASTP research projects, which could result in significant technological improvements, will receive adequate consideration for transition to the Navy.

Planning for Implementation of Applicable Technologies on the SEAWOLF Submarine

Part of the success of the ASTP program in transitioning technologies to the Navy also lies in implementing applicable technologies aboard existing submarines and those being built or designed. Defense Acquisition Circular 76-43 and Navy research, development and acquisition procedures, which address acquisition management and system design principles, recommend using a pre-planned product improvement program to provide flexibility in the system's design to accommodate future technologies. This program considers, among other things, how the submarine's structure, space, and power could be configured to allow future retrofitting of technological improvements with a minimum of disruption.

Using this technique and adequate planning and analysis are critical given the estimated 50-year life of the SEAWOLF submarine class, increasing Soviet submarine capabilities, and DARPA's and the Navy's ongoing research. However, the Navy has not developed a pre-planned product improvement program. Further, according to officials in the SEAWOLF program office and the attack submarine division of the office of the Assistant Chief of Naval Operations for Undersea Warfare, specific ASTP technologies are not being considered in designing the SEAWOLF submarine. The SEAWOLF submarine is currently being designed and the lead ship is planned to be delivered in May 1995. The officials stated that the SEAWOLF already has many capability improvements over previous classes of submarines. Nevertheless, according to ASTP officials, some technologies could be available in the near-term and could be considered for use on submarines currently being designed or built. However, the Navy has not analyzed these technologies to determine the benefits as well as the costs and design implications of incorporating them into the SEAWOLF's design.

Conclusions and Recommendations

With the $303 million appropriated for the ASTP program, DARPA is performing submarine technology research that offers the potential for significant advances to improve U.S. submarine capabilities. Opportunities exist, however, to realize the potential gain from ASTP technology research by transitioning these technologies to the Navy for further development and implementation on submarines. However, no criteria, plans, or procedures have been developed for transitioning ASTP technologies. Development of such criteria, plans, and procedures could help ensure that technologies are adequately considered by the Navy for transition so that the knowledge gained from the research is not lost.

Further, by considering ASTP research in the SEAWOLF design and including features to allow for later incorporation of technologies, the Navy could maximize the submarine's capabilities. Factors such as the potential significance of the technology improvement, its impact on the design and other submarine components, and the feasibility of the technology should be considered and evaluated to determine the overall cost-effectiveness of including these features and the design flexibility. Although all research on the technologies is not complete, consideration of information on ASTP technologies that is available could ensure that SEAWOLF capabilities can be expanded to bolster U.S. submarine advantage.

Until the Navy develops a transition strategy and evaluates the ASTP technology research for inclusion in the SEAWOLF design, the Congress cannot be assured that knowledge gained from conducting $303 million in DARPA research is fully considered for transition to the Navy for development and implementation on submarines. Accordingly, we recommend that the Secretary of Defense direct the Secretary of the Navy to

- develop criteria, plans, and procedures to ensure that ASTP technologies are adequately considered for transition to the Navy, and those most promising transferred, and
- analyze the ASTP technologies being researched to determine which ones could be cost-effectively provided for in the SEAWOLF design to facilitate their later incorporation.

Appendix I describes our assignment objectives, scope, and methodology. While we did not obtain official agency comments on a draft of this report, we discussed the contents of this report with DARPA and Navy officials, and incorporated their views where applicable. ASTP and Navy officials generally agreed with the issues we raised, and said they would focus attention on developing transition criteria, plans, and procedures.

With regard to providing flexibility in the SEAWOLF design to accomodate ASTP technologies when they are developed, the officials felt that including such flexibility would have to be based on a risk assessment of the feasibility of the technology and the impact on the design. Our work, conducted between April and December 1989, was performed in accordance with generally accepted government auditing standards.

As arranged with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution of it until 30 days from the date of this letter. At that time, we will send copies of this report to the Chairmen, Senate and House Committees on Appropriations; Chairmen, Senate and House Armed Services Committees; and the Director, Office of Management and Budget. We will also send copies to other interested parties and make copies available upon request.

This report was prepared under the direction of Samuel W. Bowlin, Director for Defense and Security Information Systems. Other major contributors are listed in appendix II.

Sincerely yours,

Ralph V. Carlone

Ralph V. Carlone
Assistant Comptroller General

Appendix I

Objectives, Scope, and Methodology

In response to a request from the Chairman, Subcommittee on Projection Forces and Regional Defense, Senate Armed Services Committee, and in subsequent discussions with the Chairman's office, we agreed to identify research efforts underway by DARPA on innovative submarine technologies and to assess plans for transitioning the research to the Navy for further development and implementation on submarines. We also agreed to determine whether the Navy is planning flexibility into the SEAWOLF and its combat system to incorporate these technologies. We performed our work primarily at DARPA in Rosslyn, Virginia; the Naval Sea Systems Command's Advanced Submarine Research and Development Office in Arlington, Virginia; and the Office of the Chief of Naval Research in Arlington, Virginia.

We interviewed numerous DARPA, Navy, and contractor officials who conduct and manage the research being performed on advanced submarine technologies and who are responsible for transitioning the technologies to the Navy. We also analyzed relevant ASTP documents, including the ASTP Long-Range Plan, program review briefings, and Navy and Defense policies and regulations. We interviewed other military department, defense agency, and DARPA officials knowledgeable about ASTP technologies and submarine capabilities.

To obtain background information on the ASTP program, we analyzed relevant public laws and congressional reports. For information about ongoing ASTP research, we interviewed the ASTP Program Manager and Deputy Program Manager, and the five program area managers.

We discussed analyses of ASTP technologies for implementation on submarines currently being built and designed with Navy SEAWOLF officials, DARPA officials, and shipyard officials. We discussed the use of preplanned product improvement techniques with the above officials, as well as officials in the Office of the Secretary of Defense.

While we did not obtain official agency comments on a draft of this report, we discussed the contents of this report with ASTP and Navy officials, and have included their comments where appropriate. We performed our work between April 1988 and December 1989, in accordance with generally accepted government auditing standards.

Appendix II

Major Contributors to This Report

Information Management and Technology Division, Washington, D.C.	Michael Blair, Assistant Director Andrew Patchan, Evaluator-in-Charge Diana Olmstead, Evaluator Sally Obenski, Evaluator